Developing a Climatology of Stratospheric Injections from Boreal Forest Fires

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Abstract

An increase in boreal fire activity and severity has been observed since the 1950s, and further increases due to climate change are expected. Recent remote sensing and *in situ* observations show that highly polluted, smoke-laden air from these fires can be injected into the upper troposphere and even the stratosphere, where it can remain for weeks. Only limited data exists on the current frequency of these injection events and the mass deposited into the stratosphere; the impacts on this region of the atmosphere have not been assessed.

We are using data sets from Aura to locate and track these injection events and develop a broader perspective of their frequency, magnitude, and mechanism. OMI and TOMS aerosol index measurements has been used as a primary filter to identify times and locations where particles are lofted high into the atmosphere, indicating possible pyrocumulonimbus activity. Seasons and geographic regions showing enhanced frequency of such events will be identified, and confirmation of these events as fire plumes will rely on CO measurements from TES and MODIS fire products.

Aura's capability to measure ozone in the lower stratosphere where trends have a large uncertainty and have not been explained, coupled with the considerable chemical information provided by TES (and also MLS and OMI for specific gases), will allow us to investigate the chemical nature of these smoke injections and thereby make a preliminary assessment of the possible effects on tropospheric and possibly stratospheric ozone.

This poster presents first results based on aerosol index results (AI) from TOMS and OMI.

Introduction

The "formation flying" of the A-Train satellites will provide several different data products which can be used in combination to address these questions regarding the impact of boreal forest fires on the lower stratosphere. With its focus on atmospheric chemistry, the Aura satellite will provide the majority of the data for this project, but complementary measurements from Aqua will be employed as well. (We look forward to using the aerosol data from PARASOL and CALIPSO). Data from the Terra spacecraft will also be extremely valuable to the current study.

Goal

We propose to answer the following questions:

- How often do mid- and high latitude fire plumes penetrate the tropopause?
- What are the usual circumstances (time of year, meteorology, etc.)?
- What particulate and gaseous emissions do these injections deliver to the LS?
- How might these inputs affect the lower stratosphere?

While the instruments on Aura will provide superior spatial resolution and will observe lower altitudes than previous instruments, we will also use archived data from Aqua, Terra and other platforms to investigate past events and develop an historical climatology of these injections of biomass burning effluent to the middle atmosphere. This poster begins to address these issues by studying enhanced Aerosol Index (AI).

Sensor	Satellite	Data Product	Notes
Aerosol Measurements			
OMI	Aura	Aerosol Optical Thickness (AOT)	
TOMS	Earth Probe	Aerosol Index	
HIRDLS	Aura	aerosol extinction profiles	2 maps/day; 10-30 km with 1.25 km vertical resolution
MODIS	Aqua, Terra	Aerosol Product	AOT, aerosol size over ocean, type over land; effective radius
MISR	Terra	aerosol profiles (10-30 km)	when appropriate scenes available; 1.25 km vertical resolution
Gases and Other Measurements			
TES	Aura	CO profile	
MODIS	Aqua, Terra	Fire & Burned Area Products, Surface Temperature	
HIRDLS	Aura	CH_4, water	2 maps/day; 1.25 km vertical resolution
TES	Aura	CH_4, NO_2, water profiles	
MLS	Aura	HCN	daily zonal mean

Aerosol Index used in this work

Instrument	Dates
NIMBUS-7/TOMS	1 Nov 1978 - 6 May 1993
EP/TOMS*	22 Jul 1996 - 31 Dec 2005
OMI TO3 *	17 Aug 2004 - 3 Jul 2006 (at present)
*where OMI and EP/TOMS overlap, OMI data is used	

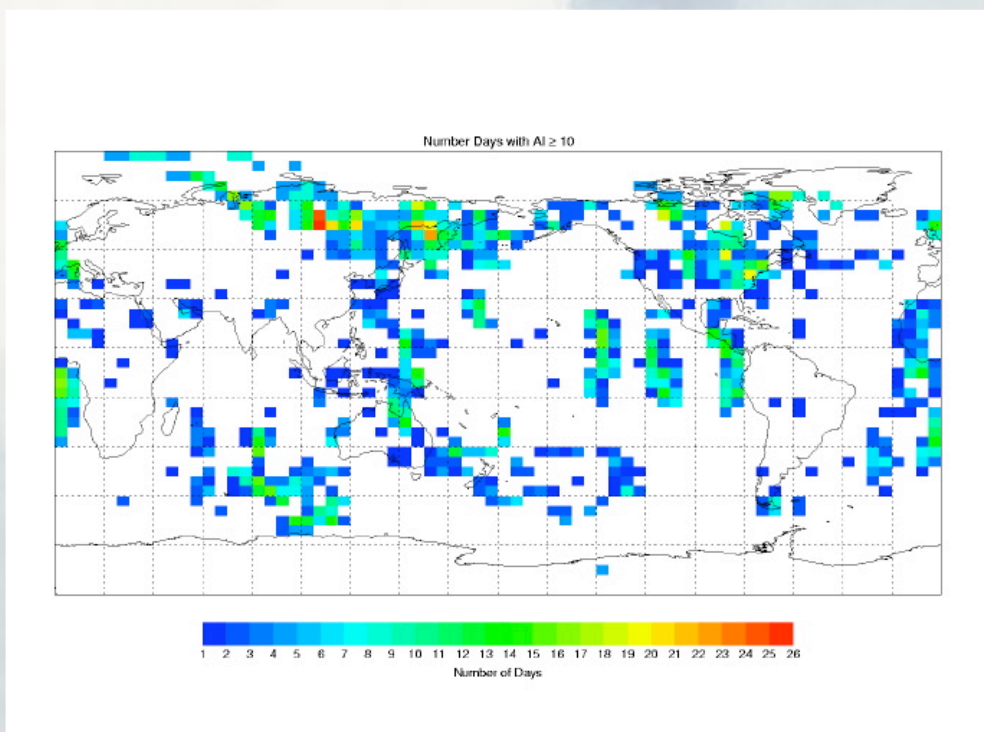

Figure 1: Each cell covers 5 degrees longitude and 4 degrees latitude, which is 16 (4x4) of the level 3 (L3) product grid cells. The plot shows the number of occurrences within each cell of AI values >= 10 over the whole data period (29 calendar years, 8838 data days).

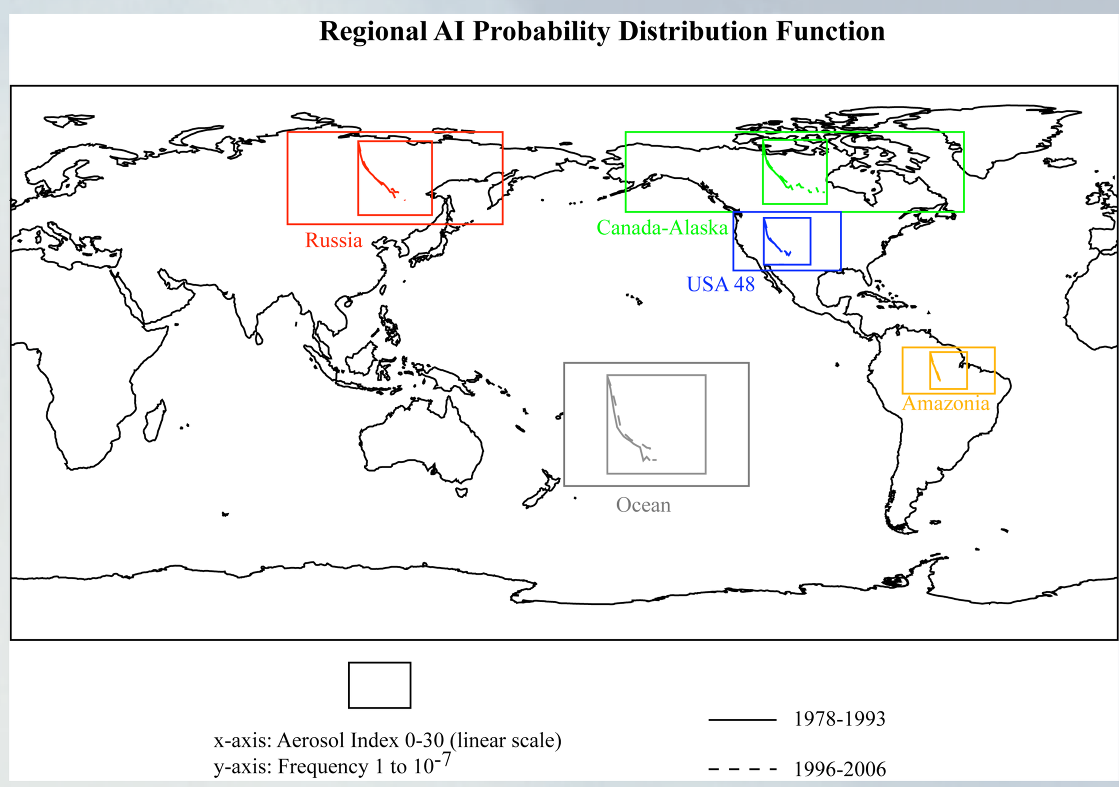

Figure 5: Different geographic regions are defined by the colored boxes. The inserts show the aerosol index probability distribution for two periods, 1978-1993 (solid) and 1996-2006 (dashed). The abscissa is 1 AI wide bins with centers from 0 to 30. The ordinate is the frequency of occurrence of a certain AI value. See Figure 6 for more detailed plots of the PDF.

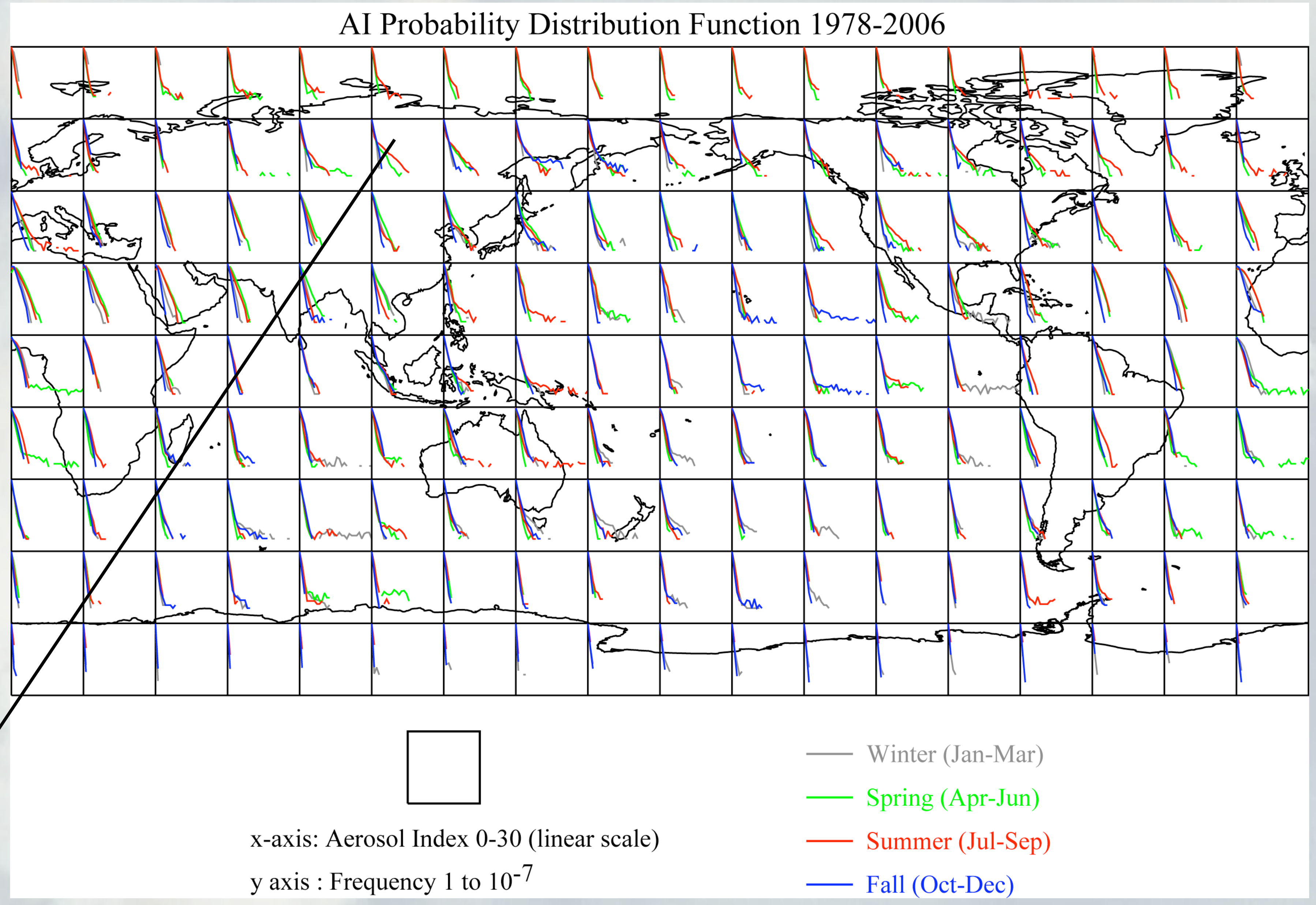

Figure 2. The PDF (actually a step function, or histogram-like approximation to the sample PDF) is plotted for a number of spatio-temporal regions. It is a normalized histogram function. The values of the histogram are the counts of AI values occurring in each region and falling into each bin (bin edges are integers and bin width = 1), and the normalization consists of division by the total counts over all bins. I.e., normalization converts counts into frequencies.

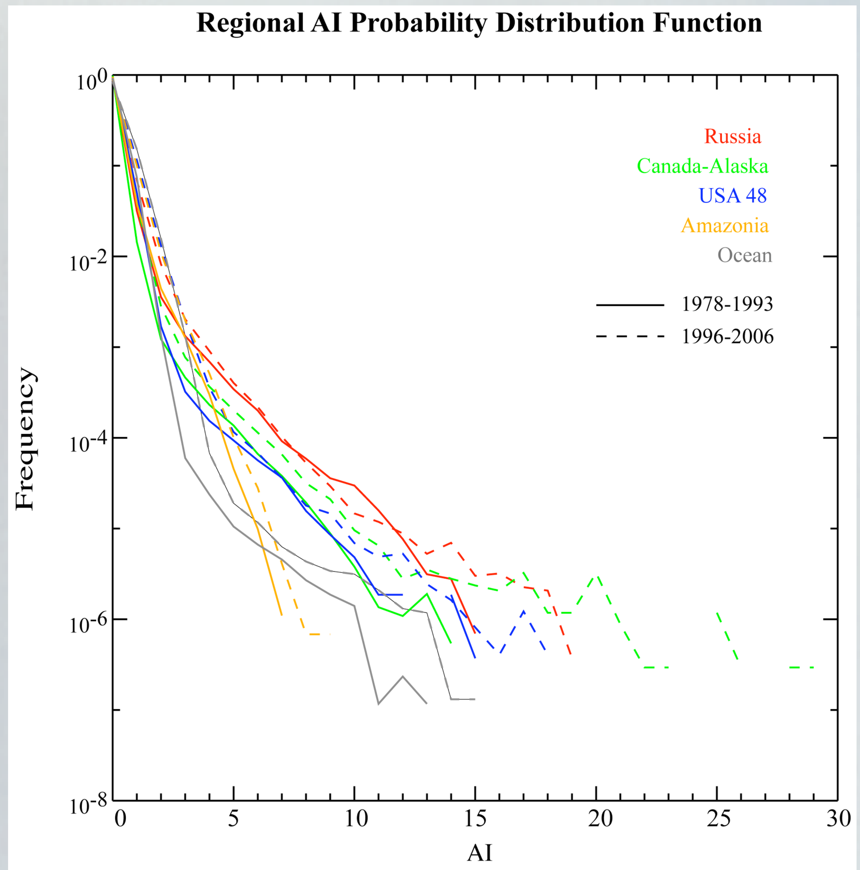

Figure 6. For the geographical regions defined in Figure 5, and coded by color, the probability distribution function of AI is given. The data set was separated in two periods, 1978-1993 (solid) and 1996 to 2006 (dashed). For every region there is an increase in frequency of occurrence of AI above 2, except for Russia, where AI 8-12 was more frequent in the earlier period. This could potentially indicate more intense pyroCB activity related to Climate Change. The increase over the ocean cell could be due to transport from Australia.

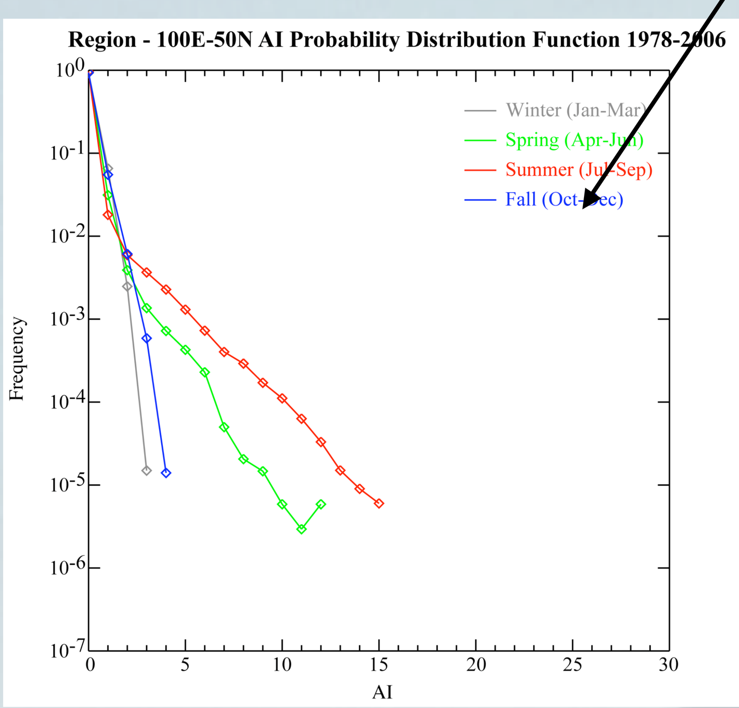

Figure 3. This figure is an enlarged version of the cell shown at 100 E, 50N in Figure 2. This shows a seasonal breakout in Siberia of enhanced AI. Is this large difference between winter/fall and spring/summer true typically or is this driven by a few years? Is this a pattern or is it driven by one bad summer? Several years were studied individually in Figure 4.

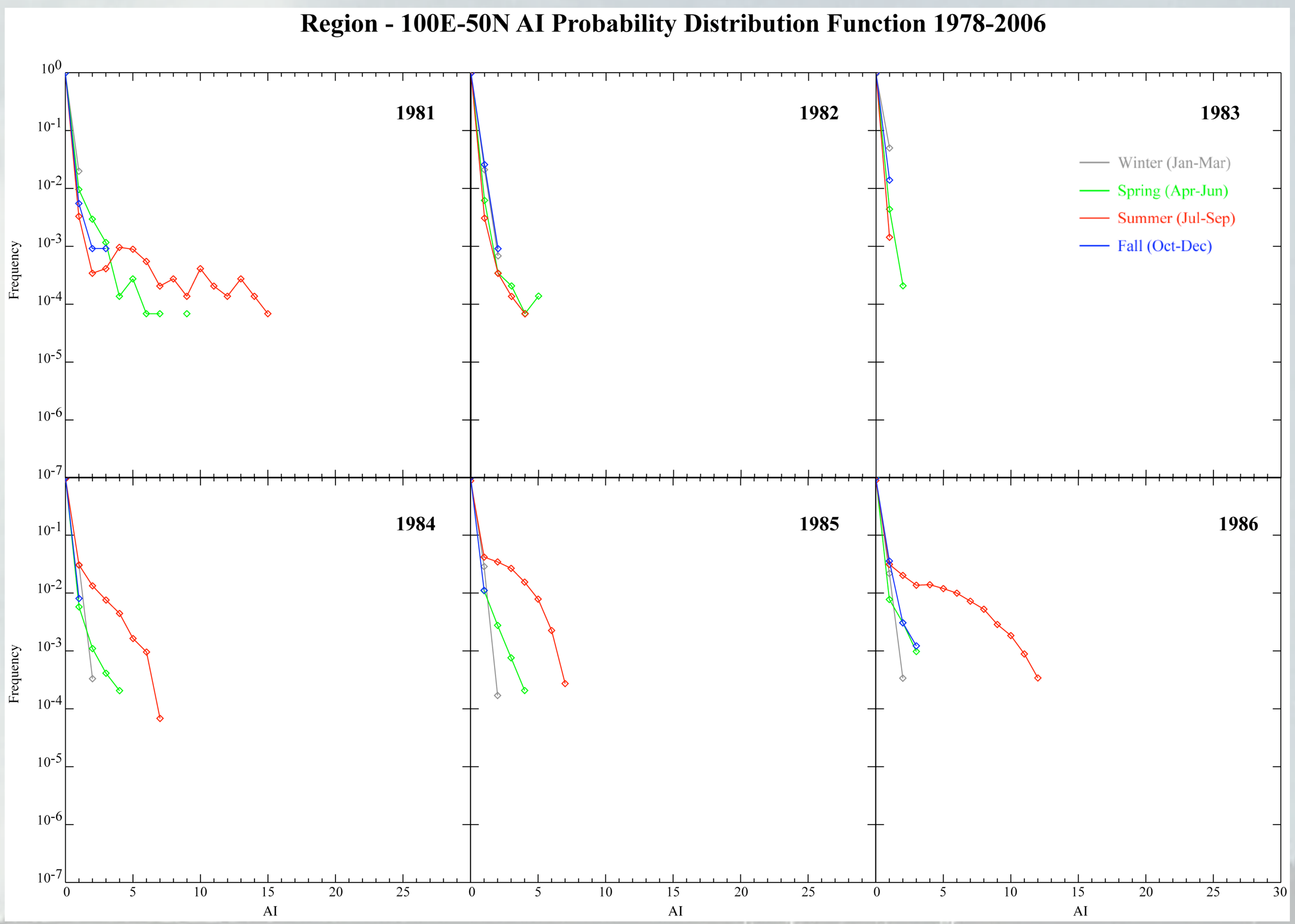

Figure 4. In order to examine the difference in Figure 3, we choose to look at several representative and consecutive years (in this case 1981-1986.) We see, over a six year period, enhanced AI in this region only occurs in some years. 1982 and 1983 did not show an increase at all in summer versus other seasons. The annual trend in Figure 3 is, therefore, driven by many individual events.

Conclusions

- Many boreal regions show an increase in AI during spring and summer. This is consistent with the burning season.
- Canada, Russia and the United States show increasing frequency of high AI events since 1996. Does this suggest a possible stratospheric loading of biomass burning effluent?

Future work

- Positively identify the high AI events that are caused by fire activity and not by other things, such as eclipses and volcanos.
- Calculate a running average of the frequency of high AI to elucidate any long term trend.
- Examine latitudinal (zonal) regions on an annual basis to avoid "case study" conclusions: weather versus climate
- Once we have identified fire-caused elevated AI, the composition of the plume can be studied (using MODIS, TES, MLS and OMI) to elucidate the effects on stratospheric chemistry

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